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S103 discovering science

Note that the times shown in the study plan overleaf do not include the time that you will need to answer questions on the DVD and the TMA, making use of the set book, attending sessions at your local or regional centre or reflecting on what you have learned and how you have learned it. Past students have also commented that *our* estimates of the times needed for the study of the DVD-multimedia activities are likely to be low.

Study Guide for Block 5

Block 5 is one of the shortest blocks in the course. However, the fact that it is short does not mean that it is less important than the other blocks. Indeed, it deals with one of the most central and unifying concepts in science — energy.

The concept of energy is one that scientists quantify very precisely, and this block will therefore require you to tackle quite a lot of algebra and calculations. Section 3, in particular, introduces a considerable amount of new mathematics which you will use in the later sections. As you study the block, you will be introduced to various strategies that will help you develop these new maths skills. It is important that you do the questions and activities at the times that you meet them in the book, since they will develop skills that are needed to understand the later sections. In particular, you will be asked to solve a variety of energy-related problems; problem solving is an important science skill, and we will develop a way of tackling problems that you will be able to generalize to a variety of different contexts.

The block is largely based on printed material, and there are no DVD-video or DVD-multimedia activities. Activity 5.1 requires you to make some measurements from a diagram of a locust's jump, and for this you will need a ruler graduated in millimetres. Activity 6.1 is an experiment that you can perform in a kitchen to estimate a value for an important property of water. For this you will require an electric kettle that is marked with its power rating in watts (usually this is on the base or side of the kettle, or you might find it in a leaflet that came with the kettle), kitchen scales that will allow you to weigh a kettle filled with water *or* a measuring jug graduated in litres or millilitres, and a clock or watch with a second hand (or a digital seconds display) that you can use for timing. If you don't possess any of these items, you may be able to borrow them from family, friends or neighbours (in the interests of science!). There are some preparations that you will need to carry out some time before you start the experiment, so we recommend that you read through the notes and comments in the Study File for Activity 6.1 up to the end of Task 1 the day before you plan to do the activity.

There are five interactive self-assessment questions on DVD to help you to assess how you are coping with the block, and you can dip into these at various stages. Part of TMA 04 is related to Block 5, and the best time to tackle this part of the assignment is immediately after you have completed this block and before you move on to Block 6.

You should begin your study of Block 5 by reading Section 1 of the book.

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5.1 DS

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5 Energy

All study times are in hours*

Week	Sections of Book 5	Total study time	DVD-multimedia, DVD-video and practical activities
1	1 Introduction		
	2 Energy conversion and conservation	$\frac{1}{4}$	
	3 Work, energy and power	$2\frac{3}{4}$	
	4 Motion under gravity	$1\frac{1}{2}$	
	5 Energy in biological systems	1	
	6 Internal energy	$2\frac{1}{2}$	$\frac{3}{4}$
	7 Electrical energy	$1\frac{1}{4}$	
	8 Energy from the Sun	$\frac{1}{2}$	
	9 Energy — an overview	$\frac{1}{4}$	

* Section 1 is very short and so a time has not been given for this section.

Note that, although the nominal schedule above is based on one week's study, many students find elements of this block challenging (for example, becoming familiar with new maths) and so two weeks have been set aside for the study of this block. This will enable you to spend more time on the parts that you find difficult.

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Study File for Block 5

Contents

Notes on activities 1
Comments on activities 15
Objectives for Block 5 24
Appendix 1 What to do if you are short of time 26

Notes on activities

You should read through the notes for each activity before attempting it. After completing an activity you should study the relevant comments in the next section of the Study File.

No estimate of time is given for activities which should take 10 minutes or less.

Activity 3.1 Reviewing the algebra introduced in Block 3

Each of parts (a)–(d) of this activity focuses on one of the key ideas of algebra that were introduced in Block 3. If you have difficulty with any part of the activity you should refer back to Boxes 3.1 and 4.1 in Block 3.

(a) *Translating words into symbols.* The *population density* of a particular biological organism is defined as the *number of organisms* divided by the *area* that these organisms occupy. Write down a word equation for this relationship. Then choose symbols to represent each of the quantities involved in the word equation, and use these symbols to write down an equation (known as an *algebraic equation*) for the relationship between population density, number of organisms and area.

(b) *Solving an algebraic equation.* If 78 blue tits occupy an area of 3.2×10^5 m^2 of oak woodland, what is the population density of these blue tits?

(c) *Rearranging an algebraic equation.* Rearrange the equation for the population density that you wrote down in part (a) to make the area the subject of the equation. Then calculate the area within which you would expect to find 50 elephants if their population density is 3.3 km^{-2}.

(d) *Expressing an algebraic equation in words.* Write down in words the meaning of the algebraic equation for the area that you derived in part (c).

(e) *How well did you handle this algebra?* Having completed this brief review of the algebra that you met earlier in the course, pause and think about how well you coped with it. Did you find it difficult or straightforward? If you found it difficult, you may wish to consider whether you should set aside more than the standard ten hours for studying this block, since there is a lot of algebra in it.

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SUP 82834 3

4.1 DS/pdf

Activity 3.2 Keeping track of symbols and equations

To keep track of the symbols that are introduced, and to help you to remember their meanings, we suggest that you produce your own glossary of symbols and their meanings as you first meet them. You will also find it helpful to note down the appropriate SI unit for the quantity represented by the symbol. So a typical entry might be something like:

F force N

If you keep your glossary handy while studying the block, you will be able to refer to it when you come across a symbol that you are unsure of, and won't have to hunt back through the text to find where the symbol was first defined. You could also include in your glossary any new mathematical notation, for example the $\propto$ symbol, which was introduced in Block 3 Box 12.1 and which means 'is proportional to'.

At the same time, we suggest that you produce a glossary of important equations as you meet them in this block. Alongside each equation you should write down the meaning of all of the symbols used and the appropriate SI unit for each. One possible way of doing this (using a familiar example from Block 3) is as follows:

$F = ma$ Newton's second law of motion — magnitude of force, F (N), is mass m (kg) multiplied by magnitude of acceleration, a ($\mathrm{m\,s^{-2}}$) — (from Block 3)

If you keep this list handy while you are studying the block, and refer to it when you are answering questions, you will find that you soon become familiar with these equations.

The equations that it is useful to have at your fingertips, and to memorize if possible, are those that are displayed as key points (on their own in boxes) and given in the section summaries. We will not expect you to remember these equations, but you must be able to recognize which equation it is appropriate to use in a particular situation, and the meaning of each term in the equation.

A single side of A4 paper, divided in half by a vertical line down the centre, should provide more than enough space for your glossary of symbols and equations. You can use one half of the page for the symbols, and the other half for the equations.

There are no comments on this activity at this stage.

At the end of Section 3

After you have completed your glossary of symbols, equations and equivalencies between units for Section 3, compare it with the list in the comments on this activity.

Activity 3.3 How do you solve problems? Part I

Part (a) of this activity requires you to answer a question that is similar in nature to many of those in this block. As you tackle it, try to be aware of the steps that you are taking — you may even want to jot them down beside your answer. After completing the question, we will ask you to review the processes you went through, and this should help you to develop general strategies for answering questions like this. It will also be useful for developing the skill of solving problems in a range of other contexts that you will meet later in the course.

(a) Here is the question to tackle first.

(i) A tennis ball with mass 55 g is travelling towards you at a speed of $30\ \mathrm{m\,s^{-1}}$. What is the kinetic energy of the ball?

(ii) If the ball's speed were doubled to $60\ \mathrm{m\,s^{-1}}$, what would its kinetic energy be?

After you have done both parts of this question, have a look at the answer in the comments section before continuing with part (b) of this activity.

(b) Now spend a few minutes thinking about how you tackled the question in part (a). You will probably find it useful to make a list of the various steps that you took, in the order that you took them. (If you made some notes while you were answering the question these will be a useful basis for your list.) There is clearly no one 'correct' response to this, but when you have made your list, compare it with lists made by another student and by an S103 tutor in the comments on this activity.

Activity 3.4 How do you solve problems? Part II

Part (a) of this activity requires you to solve a problem, and we would like you to make use of the strategy developed in Activity 3.3, which is repeated here for convenience.

1 Read the question.

2 Note down what you have to calculate and what information you are given.

3 Recall appropriate equation.

4 Substitute values in SI units into the equation and calculate the answer.

5 Check unit of answer.

6 Check number of significant figures in answer.

You should jot down the steps that you use beside your answer. After completing the problem, we will again ask you to reflect on the processes you went through, and this should help you to develop further your general strategies for answering questions like this.

(a) Here is the question to tackle first.

> The mass of a toy train is 200 g, and 0.60 J of work is done on it by a child's push. What is the speed of the train immediately after the push if it is initially stationary?

After you have done this question, have a look at the answer in the comments section before continuing with part (b) of this activity.

(b) Now spend a few minutes thinking about how you tackled the question in part (a). In particular, note down how the steps in the strategy that you developed in Activity 3.3 were applied to this problem, and any ways that you needed to adapt your strategy. There is clearly no one 'correct' response to this, but when you have listed the steps that you took, compare it with the list made by another student in the comments on this activity.

Activity 4.1 How do you solve problems? Part III

In part (a) of this activity you will apply the problem-solving strategy developed in Activities 3.3 and 3.4, and which you may have modified when doing subsequent questions, to another problem. As you tackle the problem in part (a), think about how well the steps in your problem-solving strategy match the steps you need to take to solve this problem — you may want to make some notes beside your answer. After you have completed the problem, we will ask you to reflect on how well your strategy coped with the new problem and on any changes that need to be made to it.

(a) Here is the question to tackle first.

> A diver who dives off the famous cliffs at Acapulco in Mexico hits the water at about 30 m s^{-1}. Calculate the height of the cliff. Why is your answer likely to be an underestimate? (*Hint*: think about what assumption you have made to calculate the height.)

After you have done this question, have a look at the answer in the comments section before continuing with part (b) of this activity.

(b) Now spend a few minutes thinking about how your problem-solving strategy worked for this question. Did you follow all of the steps in your general strategy? Did you need to add or modify any of the steps? Which steps did you find most difficult, and why?

Activity 5.1 Conservation of energy during a locust's jump

(*The estimated time for this activity is 40 minutes.*)

In this activity you will make a series of measurements from a diagram showing the path of a locust's jump, and will use these to investigate the energy conversions and transfers that take place. This will provide useful practice in making measurements, and in tabulating and analysing data, as well as in using the equations for kinetic and gravitational energy.

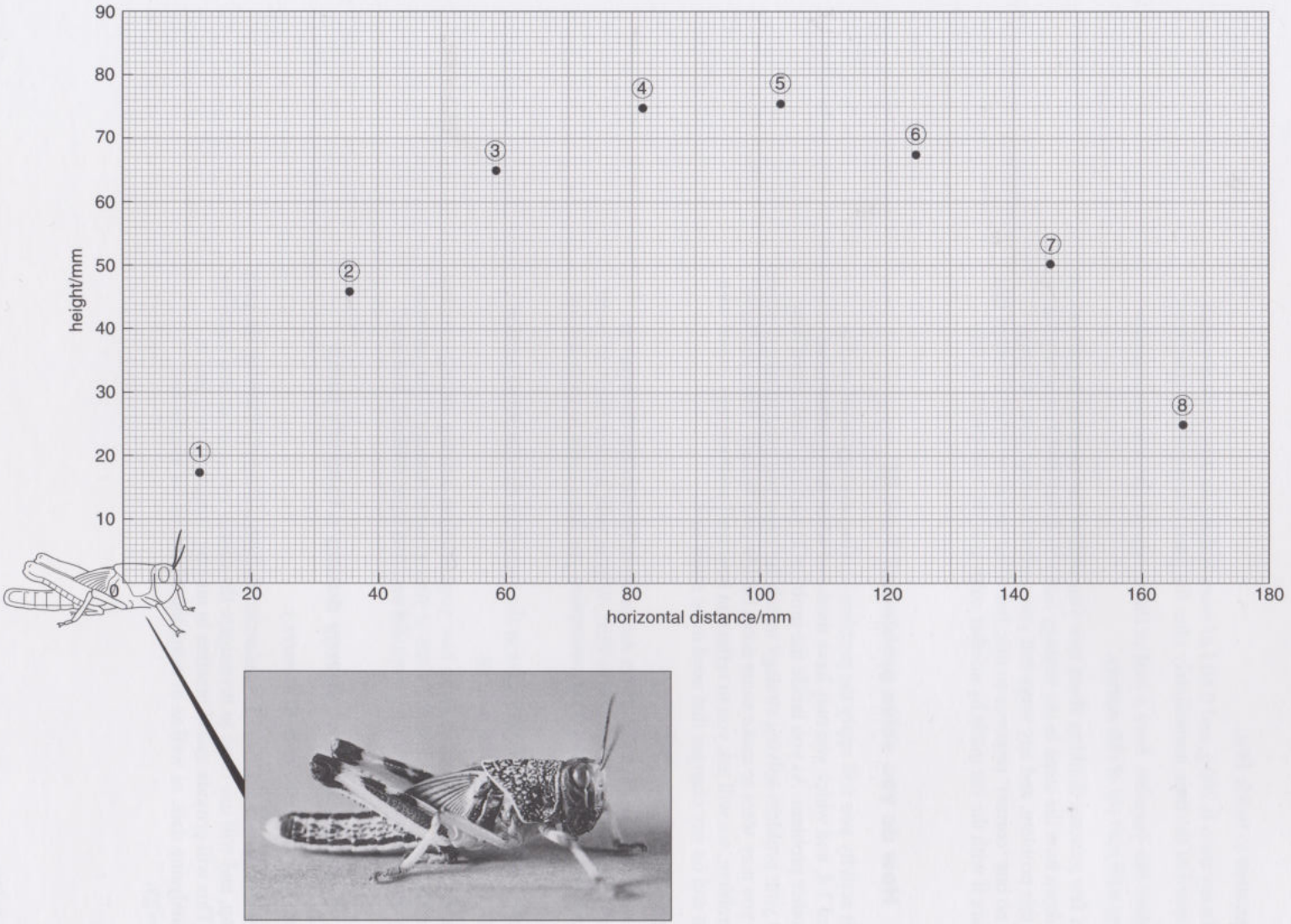

Figure 5.1.1 The path of a jumping locust. The dots indicate the positions of the centre of the body at 0.030 s intervals, and the path is shown at the actual size.

Figure 5.1.1 shows the path of a locust's jump. A juvenile locust, poised to jump, is shown inset at the origin of the graph. The jump was recorded with a high-speed video camera, the recording was played back, and the position of the centre of the locust's body was marked by dots on a television screen and these were then traced onto graph paper. The dots indicate the positions of the centre of the body of the locust every 30 ms (0.030 s) during the period of the jump. The mass of the locust was 1.2×10^{-3} kg.

The aim of this activity is to investigate energy conversions and transfers after take-off by calculating the kinetic energy and the gravitational energy corresponding to various positions of the locust in Figure 5.1.1. You will be able to check whether the sum of these energies remains the same throughout the jump, or whether energy is converted into other forms.

Task 1 Predictions about energy conversions

Sections 3 and 4 have included numerous examples of the behaviour of objects as their kinetic energy and/or gravitational energy changes. From what you have learned:

- note below your prediction for how the kinetic energy and the gravitational energy of the locust will change during its jump;

  Kenetic energy will be at its most at the begmnig and the end of the Jump. Gravitational energy will be at its most at the highest point of the Jump

- note below how you expect the changes in these two forms of energy to be related to each other.

  when the Gravitational energy is at its most, the Kenetic energy is at its least.

The measurements that follow will confirm or invalidate your predictions.

Task 2 Determining the kinetic energy of the locust

What information do you need to determine the kinetic energy of the locust? mass and speed

Kinetic energy can be calculated from $E_k = \frac{1}{2} mv^2$, so you need to know the insect's mass m and its speed v.

The mass was quoted above (1.2×10^{-3} kg), so you need to determine its speed.

Remembering that $v = \frac{d}{t}$, where d is the distance travelled in a time interval t, and that the time interval between successive positions marked in Figure 5.1.1 is 0.030 s, how can you determine the speed of the locust?

You can measure the distance between two successive positions of the locust with a ruler, and then divide this distance by the time interval (0.030 s) to get a value for the speed.

The locust slows down as it ascends and speeds up as it descends, so the measurement of speed just described will give the *mean* speed over the measured distance. You should now determine the mean speed between successive numbered positions by carrying out the following steps:

- First, use a ruler to measure the distances between successive numbered positions in Figure 5.1.1, and enter these distances in the first blank column of Table 5.1.1 (on page 7). You should give the column an appropriate heading (including the unit).
- Now work out the mean speeds by dividing the distances by the time interval (0.030 s), and enter these mean speeds (in m s^{-1}) in the next column.
- Finally, calculate the mean kinetic energy by squaring each value of mean speed and multiplying it by $\frac{1}{2} m$, i.e. 0.6×10^{-3} kg, and enter the results in the third blank column. Express the energies in units of millijoules (1 mJ = 10^{-3} J).

Task 3 Describing the kinetic energy changes

Write a couple of sentences to describe how the kinetic energy of the locust changes with position during the jump. Is the variation that you have measured consistent with your prediction in Task 1?

The kinetic energy decreases as the gravitational energy increases. The kinetic energy increases near the end of and beginning of the jump as predicted.

Once you have completed Tasks 2 and 3, read the comments on these two tasks before starting Task 4.

Task 4 Determining the changes in gravitational energy of the locust

We stressed in Section 4.2 that absolute values of gravitational energy are not meaningful, and we have always calculated *changes* in gravitational energy between two heights.

What is a convenient reference height to use in this case?

You could choose any point, but since the graph paper has a vertical scale with its zero at 'ground level', this is the most convenient reference level from which to measure gravitational energy changes.

What information do you need to know to determine the change in the gravitational energy of the locust between ground level and each of the numbered positions in Figure 5.1.1?

The change in gravitational energy is given by $\Delta E_g = mg\Delta h$, so you need to know the mass m of the locust, the acceleration due to gravity g, and the height Δh of each of the numbered positions above ground level.

The mass m of the locust is 1.2×10^{-3} kg, and for the purposes of this activity it is sufficiently precise to take the value of g as 10 m s^{-2}, so the value of mg is 1.2×10^{-2} kg m s^{-2}, or 1.2×10^{-2} N. In order to determine ΔE_g, the quantity that you are going to have to measure is Δh, and you can read this from the vertical scale on the graph.

- Read off the heights (i.e. Δh) of each of the numbered positions in Figure 5.1.1, and enter the values in the first blank column of Table 5.1.2. You should give the column an appropriate heading (including the unit).
- Calculate the gravitational energy changes, $\Delta E_g = mg\Delta h$, for each numbered position and enter the values, in mJ, in the next column of the table.

Task 5 Describing the gravitational energy changes

Write a couple of sentences to describe how the gravitational energy of the locust changes during the jump. Is the variation that you have measured consistent with your prediction in Task 1?

Once you have completed Tasks 4 and 5, read the comments on these two tasks before continuing with the activity.

Task 6 Comparing the changes in kinetic energy and gravitational energy

The kinetic energies determined in Task 2 are the mean values between successive numbered positions, so they are approximately equal to the kinetic energy *midway between the positions*. You need to compare these with the changes of gravitational energy corresponding to heights midway between the positions.

Table 5.1.1 Determining the energy changes during the locust's jump.

Interval	Distance/mm	v/m s^{-1}	E_K/mJ=10^{-3} J	ΔE_g/mJ	$E_K + \Delta E_g$/MJ
1–2	37	1.233	0.913	0.381	1.29
2–3	30	1.000	0.600	0.666	1.27
3–4	25	0.833	0.416	0.837	1.25
4–5	22	0.733	0.322	0.900	1.22
5–6	23	0.767	0.353	0.858	1.21
6–7	27.5	0.917	0.505	0.705	1.21
7–8	33	1.100	0.726	0.450	1.18

Table 5.1.2 Determining the changes in the gravitational energy of the locust.

Position	Δh/mm	ΔE_g/mJ
1	17.5	0.210
2	46	0.552
3	65	0.780
4	74.5	0.894
5	75.5	0.906
6	67.5	0.810
7	50	0.600
8	25	0.300

How can you calculate the gravitational energy change midway between positions 1 and 2?

The gravitational energy change at the mid-point must be the mean value of the gravitational energy changes at positions 1 and 2.

How do you calculate the mean value of two quantities?

You add the two quantities, and divide by two (since there are two values); we discussed how to determine mean values in Block 2.

- Calculate the gravitational energy change at the mid-points between the numbered positions and enter them in the fourth blank column of Table 5.1.1.
- Finally (and this really is the last step!) add together the values of kinetic energy and gravitational energy change in each row of Table 5.1.1, and enter the totals in the final column.

Task 7 Is energy conserved in the locust's jump?

(a) How does the sum of the kinetic energy and the gravitational energy for the locust vary during its jump?

(b) What can you deduce from these results about conservation of energy, or about other forms of energy that may be involved?

Now look at the rest of the comments on this activity.

Activity 6.1 Measuring the specific heat of water

(The estimated time for this activity is 45 minutes.)

Equipment

NON-KIT ITEMS

Electric kettle, marked with power rating (this is usually on the base or side of the kettle, or it may be in a leaflet supplied with the kettle)

Kitchen scales (or a measuring jug)

Watch or clock that indicates seconds

Aims

This practical work should help you to:

- appreciate that quantitative experiments do not require specialized equipment, and do not have to be carried out in a laboratory;
- devise a simple way to determine the specific heat of water;
- develop skills associated with planning an experiment, making and recording measurements, analysing and interpreting results.

Introduction

In this experiment you will determine the specific heat of water by supplying a measured amount of heat q to a measured mass m of water and measuring the resulting temperature rise ΔT. The specific heat of water c can be determined by making use of Equation 6.4:

$$c = \frac{q}{m\Delta T}$$

Planning the experiment

Let's consider how the three quantities on the right of Equation 6.4 can each be measured.

Measuring the heat supplied to the water

The water will be heated in an electric kettle. The kettle should have a label on it indicating its power rating in watts.

If the power rating of a kettle is 2.0 kW, how much energy is transferred from the mains electricity supply to the kettle in 20 s?

Power is energy transferred per unit time, $P = \frac{E}{t}$ (Equation 3.17), and if we rearrange this equation to make E the subject, we get $E = Pt$. Since 2.0 kW = 2.0×10^3 W, the energy transferred in 20 s is

$$E = 2.0 \times 10^3 \text{ W} \times 20 \text{ s} = 40 \times 10^3 \text{ J} = 4 \times 10^4 \text{ J}$$

So you can measure the electrical energy supplied to your kettle by simply measuring the time during which it is switched on and multiplying this by the power rating. You will need a watch or clock that indicates seconds to make this measurement. The electrical energy raises the temperature of the heating element, and heat is transferred from the element to the water. We will assume that the heat q transferred is equal to the electrical energy E supplied.

Task 1 Devising ways to measure the mass of water and the temperature rise

You will need to know the mass of the water that you are heating, and also the temperature rise — and a thermometer is not supplied! Spend a few minutes thinking about how you will determine the mass of water and the initial and final temperatures of the water. The final temperature is straightforward — you should be able to think of a suitable fixed final temperature to which you can heat the water — but determining the initial temperature is a bit more difficult.

When you've thought about this, look at the comments on this task before continuing with the activity.

Practical procedure

As discussed in the comments on Task 1, you need to fill your kettle with water *at a known temperature* at the start of the experiment. Depending on how you decide to do

this, you may need to make your initial preparations the day before you are planning to do the experiment.

Task 2 Obtaining the data

Read through all of the instructions for this task before starting the measurements. Note that these instructions assume that you will be weighing the water in the kettle; if you are using an alternative method for measuring the mass of water in the kettle you will have to modify these instructions accordingly.

Safety precaution: You should turn off the power at the socket and disconnect the kettle from the mains cable before you weigh it.

When boiling water in the kettle with the lid removed, take care not to scald yourself with the steam. Please read the advice contained in the *Practical Work Booklet* concerning the first aid treatment of scalds *now*.

- Disconnect the kettle from the mains cable, empty any water out, and measure the mass of the empty kettle using the kitchen scales. Record this mass in Table 6.1.1 (on page 11). While the kettle is empty read the power rating on the label on its base or side, and record this in Table 6.1.1 too. You should use the comments/notes column to record information about equipment and procedures you use in the experiment.
- Fill the kettle to the 'maximum level' indicator (or to the maximum that your scales will weigh) with water that is at the 'known' initial temperature, measure the mass of kettle plus water, and enter the value in Table 6.1.1.
- When you are ready to start heating the water, switch on the kettle and simultaneously observe the time to the nearest second. (It will probably be most convenient to switch on the kettle when the seconds indicator passes through zero.) Record the starting time in Table 6.1.1.
- Observe the water in the kettle with the lid removed. Ignore the small bubbles that are formed on the heating element and on the sides of the kettle, but when the water boils fiercely, switch the power off and simultaneously read the time to the nearest second. Record the switching-off time in the table.

This completes the data collection.

Analysis of results

Task 3 Calculating a value for the specific heat of water

This task can be broken down into a number of steps.

- First, calculate the mass of water in the kettle, and calculate the time interval for heating, and insert these values in the appropriate rows in Table 6.1.1.
- Insert values for the starting and finishing temperatures in the table, if you haven't already done so, and calculate the temperature change.
- Calculate the electrical energy supplied to the kettle from the power rating P and the time interval t, and insert the result in the table.
- Finally, as the electrical energy supplied is equal to the heat q transferred to the water, use this value and the values of m and ΔT to calculate a value for the specific heat of water, and insert this in the final row of the table.

Now look at a set of results obtained by a member of the Course Team in the comments section before continuing with this activity.

Review

You will appreciate that the experiment that you have done has been a bit 'rough and ready', but hopefully it has convinced you that you can obtain estimates for a quantity like the specific heat of water using simple equipment and techniques. After all, before making this measurement you may not have known whether the specific heat of water was 400 J kg^{-1} $°C^{-1}$, 4 000 J kg^{-1} $°C^{-1}$ or 40 000 J kg^{-1} $°C^{-1}$. You should now spend a few minutes reviewing the experiment. To help you do this, work through Task 4.

Task 4 Uncertainties in the measurements

We introduced the idea of uncertainties associated with experimental measurements in Block 2 Box 2.1 and Activity 2.1, and you should now consider what factors lead to uncertainties in the value that you have obtained for the specific heat of water. In particular, you should note down:

(a) your estimates of the uncertainties in the measurements of the mass of water used, the temperature difference and the time interval; make a note of these uncertainties in the 'comments' column of the appropriate rows of Table 6.1.1;

(b) whether all of the electrical energy supplied to the kettle was transformed into internal energy of the water, and if not, where it went, and what effect this had on the measured specific heat;

(c) how you could improve on the experiment, using different equipment or a different method, to get a more accurate value for the specific heat.

Read the comments on Task 4 before continuing with this activity.

Task 5 Writing a conclusion for the experiment

To conclude this activity, write a conclusion for the experiment that summarizes the result you obtained, that compares it with the accepted value, and that indicates the main reasons for the difference between the two values. (Try to do this in three sentences.)

Now look at the rest of the comments on this activity.

Table 6.1.1 Results from an experiment to measure the specific heat of water. (Make sure that you record the unit for each quantity as well as its numerical value.)

	Results	Comments/notes
mass of empty kettle		
mass of kettle + water		
mass m of water in kettle		
power rating P of kettle		
starting time (power on)		
finishing time (power off)		
time interval t for heating		
starting temperature		
finishing temperature		
temperature change ΔT		
electrical energy supplied $E = P \times t$		
specific heat of water $c = \frac{q}{m\Delta T}$		

Activity 6.2 Measuring the latent heat of vaporization of water

(*The estimated time for this activity is 20 minutes.*)

An account follows (on page 13) of an experiment to measure the latent heat of vaporization of water carried out by a member of the Course Team in his kitchen. It is written using a structure and style that we would encourage you to adopt when you are asked to produce an account of an experiment. You should first read the account and the comments beside it, and then tackle the three tasks below.

Task 1 Analysing the results

Complete the table of results (Table 6.2.1) by filling in the two blank spaces, and then calculate the energy supplied during the time interval for heating. Use these results to calculate a value for the latent heat of vaporization of water. You should explain and lay out your calculations in a way that would be intelligible to a tutor who was unfamiliar with the experiment.

Task 2 Assessing the uncertainties in the experiment

Look back at the account of the experiment, and think back to your experience with the specific heat experiment (Activity 6.1). Note down below what you think are likely to be the main sources of uncertainty in measuring the latent heat of vaporization of water in this way.

Task 3 Writing a conclusion

Write a sentence that could act as the conclusion to the experiment; this needs to state clearly the result of the measurement.

Account	Comment
An experiment to measure the latent heat of vaporization of water	The title indicates the subject of the experiment.
Abstract An experimental measurement of the latent heat of vaporization of water was carried out using equipment available in the kitchen. The value obtained for the latent heat was ..... Various suggestions are made for ways in which a more accurate value could be obtained.	In the abstract (sometimes called a 'Summary') you summarize in a few sentences what you did and the result you obtained. This allows the reader to assess whether they are interested in reading what follows. Although it appears at the beginning, the abstract will often be the last part of the account that you write.
Introduction The aim of this experiment was to measure the latent heat of vaporization of water, that is the energy required to convert one unit of mass of liquid water into vapour. Water was boiled in an electric kettle for a measured period of time, and the decrease in the mass of water in the kettle due to vaporization was measured. The energy supplied was calculated from the known power rating of the kettle, and the latent heat was then calculated by dividing the energy supplied by the mass change.	In the introduction you briefly set out the purpose of the experiment, and how it was carried out, in broad outline. The details come in the next section.
Method A jug kettle, with a capacity of 2 litres and a power rating of 2.0 kW (marked on a label on the base), was filled about half-full with water from the tap, and heated until the water boiled. It was switched off, disconnected from the mains lead, and the lid removed. Then it was carefully weighed on kitchen scales and the mass of kettle plus water recorded. The scales were the type with a spring under the scale pan; they were graduated in 25 g divisions, and could measure a maximum mass of 5 kg. The kettle was then removed from the scales and reconnected to the mains lead. The power was switched on and simultaneously the time was noted using a digital watch with a seconds display. The kettle was switched off after 4 minutes (to the nearest second) and then reweighed. Cooling of the kettle and water during the first weighing operation was minimized by carrying this out as quickly as possible; only about half a minute elapsed between switching off the kettle after it had first boiled and switching on again for the 4 minute heating period.	In the method section you describe how you carried out the experiment. You need to include details of the equipment that you used, any special precautions that you took to reduce uncertainties (e.g. minimizing the time required for the first weighing in this case), and any problems encountered. It is often useful to include a diagram showing how the equipment was set up, or illustrating some detail of the experiment. The length of this section will depend on the complexity of the experiment. If you are writing an account of an experiment in which you have followed a procedure described in some student notes, then there is no need to repeat all of the details that are in the notes — a brief summary would generally be enough. Note that scientists generally write their accounts in an impersonal 'passive' style, e.g. 'a jug kettle was filled' rather than 'I filled the jug kettle'.
Results **Table 6.2.1** Results from an experiment to measure the latent heat of vaporization of water. power rating of kettle 2.0 kW initial mass of kettle plus water 1 250 g final mass of kettle plus water 1 025 g mass of water converted into vapour time power switched on (h:min:s) 10:42:00 time power switched off (h:min:s) 10:46:00 time interval for heating	The results section is where you present the measurements or observations that you have made. This is often done most neatly using tables and/or graphs, and you should make sure that these are appropriately labelled and the correct units are included. This section would also contain the analysis of the results and the calculation of the final answer, but these are not included here because you will be doing them in Task 1.

Activity 9.1 Reviewing your study of Block 5

This block has the greatest amount of maths per study week of any of the blocks in *Discovering Science*. It has introduced quite a lot of new maths, it has involved you in doing a large number of calculations using a variety of algebraic equations, and it has required you to develop a strategy for solving energy-related problems.

How do you think your ability to tackle these areas has changed since you started to study this block? Use the 'questionnaire' below to assess this by indicating on each line how you felt at the start of the block and how you now feel, perhaps using different letters or symbols to distinguish the two responses.

For those aspects that you feel least confident about, how do you think that you can become more confident?

	no idea about this	struggling	fairly confident	confident in most cases	very confident
Using symbols for physical quantities					
Using proportionalities					
Deciding which equations are required					
Rearranging and solving algebraic equations					
Combining equations to solve problems					
Substituting values in equations and calculating the correct answer					
Getting the units right					
Getting the significant figures right					
Setting out the answers to maths questions					
Having a strategy for solving problems					

Comments on activities

Activity 3.1

(a) Population density *equals* number of organisms *divided by* area occupied, or:

$$\text{population density} = \frac{\text{number}}{\text{area}}$$

We will represent the population density by p, the number of organisms by N, and the area by A. Then the word equation becomes:

$$p = \frac{N}{A}$$

Note that we stated explicitly the meaning of each of the symbols we used above; it is important to remember to do this when you introduce new symbols, otherwise readers (including you at a later time!) will not be able to understand what you have written. We used the symbols that many biologists use to represent these quantities, but you may have chosen different letters to represent the quantities in the equation, or you may have used lower case letters rather than capital (upper case) letters, or vice versa. Scientists often use a letter that is the initial letter of the quantity that it represents (as we have done here), since it makes it much easier to remember what the letter stands for. Also, they sometimes make use of letters from the Greek alphabet: for example, in Block 3 you met the symbol ρ, the Greek lower case letter rho, which is conventionally used to represent the density of a substance.

(b) The population density is calculated using the equation $p = \frac{N}{A}$ from part (a). Since $N = 78$, and $A = 3.2 \times 10^5\ \text{m}^2$, then

$$p = \frac{N}{A} = \frac{78}{3.2 \times 10^5\ \text{m}^2} = 2.437\,5 \times 10^{-4}\ \text{m}^{-2}$$

Since the number and area were given to two significant figures (Block 2, Box 2.1), the answer should be expressed to the same precision, so

$$p = 2.4 \times 10^{-4}\ \text{m}^{-2} \text{ (to two sig. figs)}$$

The population density of blue tits is 2.4×10^{-4} per square metre.

Note that when solving a problem like this one, it is good practice to write down the equation that you are going to use ($p = \frac{N}{A}$ in this case), and the values that you are going to substitute into it ($N = 78$, and $A = 3.2 \times 10^5\ \text{m}^2$ in this case), rather than simply writing down the answer. If you get the wrong answer, this allows you to go back and check how you did the calculation. It is also important to remember that the symbols that are used for physical quantities such as area *represent the units as well as the numbers*. It would therefore be *wrong* to write down $A = 3.2 \times 10^5$ and you should be careful to avoid making this (common) error. However, note that N is just a number — the number of blue tits — so this doesn't have any unit.

(c) We start with the equation $p = \frac{N}{A}$, and make use of the fact that the two sides of the equation remain equal if we multiply or divide them both by the same quantity. So the first step is to bring A to the top of the equation by multiplying both sides by A:

$$p \times A = \left(\frac{N}{A}\right) \times A = N$$

since the As cancel out on the right of the equation. We now make A the subject of the equation by dividing both sides by p, thus cancelling the p from the left side:

$$\frac{p \times A}{p} = \frac{N}{p}$$

so

$$A = \frac{N}{p}$$

To find the area within which we expect to find 50 elephants we have to substitute $N = 50$ and $p = 3.3\ \text{km}^{-2}$ into this equation:

$$A = \frac{N}{p} = \frac{50}{3.3\ \text{km}^{-2}} = 15\ \text{km}^2 \text{ (to two sig figs)}$$

Note that the answer is given to only two significant figures because the population density was given to that precision. In passing, it is worth noting that the area calculated above is a mean value: elephants in a game park are not uniformly distributed in the way that atoms in a solid are!

(d) The area occupied by a particular number of organisms is the number of organisms divided by the population density.

(e) If you found this activity difficult, then we recommend that you look again at Boxes 3.1 and 4.1 in Block 3, and at the 'Algebraic manipulation' software on the Block 3 DVD-ROM. Also you may need to plan to spend extra time on the boxes that introduce new aspects of algebra in this block. You will get plenty of opportunities to develop and practise the skills of using algebra in the questions and activities that are part of this block.

Activity 3.2

At the end of Section 3

There is no 'correct' list of symbols and equations for your glossary — what you include is up to you. However, you may have difficulty in distinguishing the important equations from all of the others. One way of identifying the important equations is to pick out those that are displayed as a key point in their own box or those that appear in the section summaries.

Figure 3.2.1 shows the list that one member of the Course Team produced after reading Section 3.

At the end of Box 3.4 we suggested that you might also like to include equivalencies between units in your glossary, and the following have appeared in Section 3.

$1\ \text{N} = 1\ \text{kg m s}^{-2}$

$1\ \text{J} = 1\ \text{N m} = 1\ \text{kg m}^2\ \text{s}^{-2}$

$1\ \text{W} = 1\ \text{J s}^{-1}$

Glossary of symbols and equations used in Block 5

W	work	J
F	force	N
d	distance	m
a	acceleration	$m\,s^{-2}$
m	mass	kg
v	speed	$m\,s^{-1}$
E_k	kinetic energy	J
E_i	internal energy	J
P	power	W
$\propto$	means "is proportional to"	
Δ	delta, means "the change in"	

$W = Fd$	work W (J) done by force F (N) moving through distance d (m) – (Equation 3.6)
$E_k = \frac{1}{2}mv^2$	kinetic energy E_k (J) is related to mass m (kg) and speed v ($m\,s^{-1}$) – (Equation 3.12)
$P = \frac{E}{t}$	power P (W) is rate of conversion of energy E (J) – (Equation 3.17)
$F = ma$	Newton's second law of motion – magnitude of force, F (N), is mass m (kg) multiplied by magnitude of acceleration, a ($m\,s^{-2}$) – (from Block 3)
$a = \frac{v}{t}$	acceleration a ($m\,s^{-2}$) is rate of change of speed v ($m\,s^{-1}$)

Figure 3.2.1 Glossary of symbols and equations for Section 3 produced by a member of the S103 Course Team. Note that the last two equations were introduced in Block 3.

We recommend that you continue to add new symbols and equations to your list as you study the rest of the block. Your completed list will be useful when you are studying later blocks, so keep it in your Study File for future reference.

Activity 3.3

(a) Here is the answer to the question.

(i) We need to determine the kinetic energy of the ball, and we are told its mass and its speed. The kinetic energy is calculated using Equation 3.12:

$$E_k = \tfrac{1}{2}mv^2$$

The mass m is 55 g, which is 55×10^{-3} kg, or 5.5×10^{-2} kg in scientific notation, and the speed v is $30\,m\,s^{-1}$, so:

$$E_k = \tfrac{1}{2} \times 5.5 \times 10^{-2}\,kg \times (30\,m\,s^{-1})^2$$

$$= \tfrac{1}{2} \times 5.5 \times 10^{-2} \times 900\,kg\,m^2\,s^{-2} = 24.75\,kg\,m^2\,s^{-2}$$

Now $1\,kg\,m^2\,s^{-2} = 1\,J$. Also since the values in the question are given to only two significant figures, the answer needs to be rounded to two significant figures. So:

$$E_k = 25\,J$$

Note that we converted the mass from grams into the basic SI unit of kilograms before substituting into the equation, as advised in Box 3.4.

(ii) If the speed were doubled to $60\,m\,s^{-1}$, then:

$$E_k = \tfrac{1}{2} \times 5.5 \times 10^{-2}\,kg \times (60\,m\,s^{-1})^2 = 99\,J$$

Note that doubling the speed increases the kinetic energy by a factor of four, 2^2, because the kinetic energy is proportional to v^2.

Please attempt part (b) of this activity before reading the following comments.

(b) You may have found this question straightforward, and therefore found it difficult to comment on your method of answering it other than to say 'I did it'. Nevertheless it is useful to develop a strategy that can be used for more complex problems.

Here is the list made by a student after doing the question in part (a):

Saw what I had to calculate (kinetic energy)

Looked for an equation ($E_k = \frac{1}{2}mv^2$)

Worked out the answer

When we asked an S103 tutor to note down the steps that she took, she produced the following list:

1 I read the question.

2 Noted down what I had to calculate (E_k) and what I was given (m, v).

3 Recalled equation $E_k = \frac{1}{2}mv^2$.

4 Substituted values in SI units into the equation and calculated the answer.

5 Checked unit of answer was correct SI unit (J for energy).

6 Checked that number of significant figures used was correct (two in this case).

How did your list compare with these two? Note that the main points in both lists are the same, but the tutor has listed explicitly steps 1, 5 and 6 that the student didn't write down, but probably carried out, and the tutor also mentioned that she had substituted values in SI units. Steps 5 and 6 are important in all calculations, and you should develop the habit of always asking yourself at the end of a calculation whether you have quoted the correct unit (we gave advice on this in Box 3.4) and the correct number of significant figures (discussed in Box 2.1 in Block 2).

The strategy that the tutor used is stated in general terms below, and we suggest that you try using a strategy like this as you tackle the questions in this block. You will need to adapt and extend this strategy as you come across different types of problems in later questions and activities.

1 Read the question.
2 Note down what I have to calculate and what I am given.
3 Recall appropriate equation.
4 Substitute values in SI units into the equation and calculate the answer.
5 Check unit of answer.
6 Check number of significant figures in answer.

Activity 3.4

(a) We are asked to calculate the speed of the train, and are told its initial speed (zero), its mass and the work done by the force. Assuming there is no friction, when 0.60 J of work is done on the train, its kinetic energy must increase by the same amount because energy is conserved, so

$$E_k = 0.60\,\text{J}$$

Using Equation 3.14 for the speed and converting the mass of 200 g to 0.200 kg:

$$v = \sqrt{\frac{2E_k}{m}} = \sqrt{\frac{2 \times 0.60\,\text{J}}{0.200\,\text{kg}}} = \sqrt{6}\ \text{m s}^{-1}$$

$$= 2.449\,\text{m s}^{-1} = 2.4\,\text{m s}^{-1}\ \text{(to two sig figs)}$$

Here we have used the principle that if we substitute values into an equation in the correct SI units (J and kg in this case), then the answer will be in the appropriate SI unit (m s^{-1} for speed here). You might have worked out the final unit for yourself by using the fact that $1\,\text{J} = 1\,\text{kg m}^2\,\text{s}^{-2}$. From this it follows that

$$\sqrt{\frac{\text{kg m}^2\,\text{s}^{-2}}{\text{kg}}} = \sqrt{\text{m}^2\,\text{s}^{-2}} = \text{m s}^{-1}$$

which confirms the correctness of the unit we used above.

Note that when rounding this answer to two significant figures you only take note of the third digit in the number; since it is 4 in this case rounding to two significant figures leaves the second digit unchanged. You must *not* round the number one stage at a time; it would be *wrong* to say 2.449 = 2.45 to three sig. figs, so it is 2.5 to two sig. figs.

Please attempt part (b) of this activity before reading the following comments.

(b) A student's notes on how she went about solving the problem are printed (in Table 3.4.1) beside the six point list that the tutor produced in Activity 3.3.

Did you use a similar strategy to this one in tackling the problem? There's no set way of solving problems, and you may have additional steps that you find helpful to list separately. But if any of the steps here are missing from your strategy, you should think about whether they should be included.

The third step outlined above is the tricky one. The student realized that this step would really be better split into two steps: she decided that she should first think about what concepts are involved in the problem, and then find the equations that related to those concepts. When doing questions from the book or in assignments you can often get an clue to the relevant concepts from the block or section where they appear (— if it is in Block 5 it must involve energy in some way!). But then you need to look for other clues; for example, if motion is involved, then maybe kinetic energy is relevant, and as you'll see in Section 4 if the height of something is changing then gravitational energy probably comes into the problem.

By now you should be automatically thinking about the unit when you write down the answer to a calculation, and Box 3.4 gave useful advice that should help you to get the unit right. You should also be checking that you are quoting the appropriate number of significant figures.

The student's adapted strategy was as follows:

1 Read the question.
2 Note down what I have to calculate and what information I am given.
3 Think what concepts are involved.
4 Recall appropriate equation(s).
5 Substitute values in correct basic SI units into the equation and calculate the answer.
6 Check unit of answer.
7 Check number of significant figures in answer.

Table 3.4.1 See the answer to Activity 3.4.

1	Read the question.	Easy bit!
2	Note down what I have to calculate and what information I am given.	Calculate v, given W, m.
3	Recall appropriate equation.	Hard! I knew speed was related to kinetic energy and mass (Equation 3.14), but I couldn't find an equation that related speed and work. Then realized work done equals energy transferred, and this must be equal to kinetic energy because of energy conservation. So appropriate equations are $E_k = W$, and $v = \sqrt{\frac{2E_k}{m}}$.
4	Substitute values in SI units into the equation and calculate the answer.	Energy needs to be in J, mass needs to be in kg so convert 200 g to 0.200 kg.
5	Check unit of answer.	Since I used SI units for energy (J) and mass (m), I knew the speed would be in the SI unit m s^{-1}.
6	Check number of significant figures in answer.	Work given to two sig. figs, so I gave answer to two sig. figs.

Activity 4.1

(a) In this problem we need to calculate the height of the cliff, and we are only told the speed at which the diver hits the water. We assume that we can neglect air resistance. Then because energy is conserved, the gravitational energy that the diver loses is all converted into kinetic energy. If the height of the cliff is Δh, then her gravitational energy decreases by $\Delta E_g = mg\Delta h$ by the time she hits the water, and her kinetic energy at this point is $E_k = \frac{1}{2} mv^2$, so

$$mg\Delta h = \tfrac{1}{2} mv^2$$

We now need to rearrange this equation to get Δh as the subject. Dividing both sides by mg gives:

$$\Delta h = \frac{v^2}{2g}$$

and if we substitute $v = 30\ \text{m s}^{-1}$, and $g = 9.8\ \text{m s}^{-2}$, then:

$$\Delta h = \frac{(30\ \text{m s}^{-1})^2}{2 \times 9.8\ \text{m s}^{-2}} = 46\ \text{m (to two sig. figs)}$$

(Note that you didn't need to know the mass of the diver; all divers will have the same acceleration, g, so they would all hit the water with the same speed, irrespective of their mass.)

This is likely to be an underestimate of the cliff height because we have assumed there is no air resistance. In fact, the diver will be slowed slightly because of air resistance, so the speed with which she hits the water will be lower than if there were no air resistance. This means that the value of Δh as calculated above will be too small.

Please attempt part (b) of this activity before reading the following comments.

(b) A student followed the strategy outlined in the list of points at the end of the comments on Activity 3.4 and his notes are shown beside these points in Table 4.1.1.

The student thought that this strategy worked well for this problem, apart from step 4. In this case, equations need to be combined and rearranged to solve for Δh, rather than simply substituting into an 'off-the-shelf' equation, so the student decided to make this explicit in his list of steps, and his revised list is shown below. He thought that the difficult step was again step 3.

When doing calculations like these it is always worth pausing at the end and asking yourself if the answer is reasonable. If your answer for the height of the cliff came to 4 600 m, or to 4.6 m, you might justifiably think that it would be worth checking your answer! You won't always know what a 'reasonable' answer is, and you won't detect small errors in this way, but tutors often get assignments with answers like 'So the mass of the man is 700 kg.' or 'Speed of car = $2.3 \times 10^{-3}\ \text{m s}^{-1}$', which are obviously unreasonable. Errors like these can be discovered by making an estimate of the answer using approximate values. So a final point to add to your list of steps might be to check if the answer is reasonable.

The modified list of steps is now as follows:

1 Read the question.
2 Note down what I have to calculate and what information I am given.
3 Think what concepts are involved.
4 Recall appropriate equation(s).
5 Combine equations and rearrange to solve for required quantity.
6 Substitute values in correct basic SI units into the equation and calculate the answer.
7 Check unit of answer.
8 Check number of significant figures in answer.
9 Check that the answer is reasonable.

Table 4.1.1 See the answer to Activity 4.1.

1	Read the question.	OK
2	Note down what I have to calculate and what information I am given.	Calculate Δh, given v.
3	Think what concepts are involved.	Assumed this was about energy conservation, gravitational energy converted into kinetic energy.
4	Recall appropriate equations.	Needed the equations $\Delta E_g = mg\Delta h$, $E_k = \frac{1}{2} mv^2$. Then needed to equate gravitational and kinetic energy changes, and rearrange to solve for Δh.
5	Substitute values in correct basic SI units into the equation and calculate the answer.	v is in m s^{-1}, g is in m s^{-2}.
6	Check unit of answer.	Since I used SI units for speed and for g, I knew height unit would be SI unit of length m.
7	Check number of significant figures in answer.	Speed given to two sig. figs, so I gave answer to two sig. figs.

Activity 5.1

Tasks 2 and 3

Results obtained (up to the end of Task 3) by a member of the Course Team are given in Table 5.1.3. Your distance values may differ from those in the table by half a millimetre or so, since it is difficult to make measurements more precisely than that.

Table 5.1.3 Completed version of Table 5.1.1 — up to the end of Task 3. Determining the kinetic energy of the locust.

Interval	distance/mm	v /m s^{-1}	E_k/mJ
1–2	37	1.233	0.913
2–3	30	1.000	0.600
3–4	25	0.833	0.417
4–5	22	0.733	0.323
5–6	23	0.767	0.353
6–7	27.5	0.917	0.504
7–8	33	1.100	0.726

The kinetic energy decreases between positions 1 and 4, reaches a minimum value between positions 4 and 5, and then increases again. The kinetic energy changes more slowly near the top of the jump. You may have predicted this based on your experience of how the speed of objects change when thrown up in the air.

Now continue with Task 4 in the notes for this activity.

Tasks 4 and 5

Results obtained (up to the end of Task 5) by a member of the Course Team are given in Table 5.1.4.

Table 5.1.4 Completed version of Table 5.1.2. Determining the gravitational energy of the locust.

Position	Δh /mm	ΔE_g/mJ
1	17.5	0.210
2	46	0.552
3	65	0.780
4	74.5	0.894
5	75.5	0.906
6	67.5	0.810
7	50	0.600
8	25	0.300

The gravitational energy increases between positions 1 and 4, reaches a maximum value between positions 4 and 5, and then decreases again. The gravitational energy changes more slowly near the top of the jump.

Now continue with Task 6 in the notes for this activity.

Task 6

Results obtained by a member of the Course Team are shown in Table 5.1.5.

Task 7

(a) The sum of kinetic energy and gravitational energy (shown in the final column of Table 5.1.5) decreased slightly between the start of the jump and the end. The difference was about 0.11 mJ, which is about 9% of the initial value.

(b) The results certainly do not confirm the conservation of energy; the sum of the kinetic and gravitational energies is *not* conserved, and these are the only two forms of energy that can be measured from Figure 5.1.1. But the results do not disprove conservation of energy either. As you know, air resistance will lead to some of the initial energy of the locust being converted into internal energy of the locust and internal energy of the air, so the decrease in the sum $E_k + \Delta E_g$ identified in the measurements could be accounted for by an increase in internal energy. Our belief in the validity of energy conservation means that we should interpret the values in Table 5.1.5 as indicating that about 0.11 mJ were transformed into internal energy during the jump, and that the sum of the kinetic, gravitational and internal energies was conserved.

In passing we will point out another aspect of the locust's jump that is interesting from an energy viewpoint. Locusts can jump far better than would be expected on the basis of the size of their rear leg muscles and the speed with which these muscles can contract. What actually happens is that the locust fully bends its back legs (the equivalent of you crouching down before jumping), and it then 'locks' its legs in this bent position (see Figure 5.1.1). The 'jumping' muscles then contract and become rather like taut elastic bands, so strain energy (Section 4.4) is stored in the leg-muscle system. When the 'lock' is released, all of the stored strain energy is rapidly converted into kinetic energy as the locust propels itself into the air.

Table 5.1.5 Completed version of Table 5.1.1. Determining the energy changes during the locust's jump.

Interval	distance/mm	v /m s^{-1}	E_k/mJ	ΔE_g/mJ	$E_k + \Delta E_g$/mJ
1–2	37	1.233	0.913	0.381	1.29
2–3	30	1.000	0.600	0.666	1.27
3–4	25	0.833	0.417	0.837	1.25
4–5	22	0.733	0.323	0.900	1.22
5–6	23	0.767	0.353	0.858	1.21
6–7	27.5	0.917	0.504	0.705	1.21
7–8	33	1.100	0.726	0.450	1.18

Activity 6.1

Task 1

Measuring the mass of water in the kettle. There are various ways that you might have thought of doing this. Perhaps the simplest is to use kitchen scales to weigh the kettle when it is empty, and weigh it again when it is full of water. The difference between the two measurements is then the mass of water. (If your scales only measure in pounds, then you will need to convert the measurement into kilograms using the conversion factor 1 pound = 0.454 kilograms.)

Alternatively, you could weigh some water in a jug and then pour it into the kettle, again taking account of the mass of the jug.

If you don't have any suitable kitchen scales, you could use a measuring jug to pour a measured volume of water into the kettle. The mass m of the water can be calculated from its density ρ and the volume V, using the equation for density $\rho = \frac{m}{V}$, which can be rearranged to make m the subject: $m = \rho V$. The density of water is $1\,000\,\text{kg m}^{-3}$, or $1.000\,\text{kg litre}^{-1}$, so the mass in kilograms is related to the volume in litres by the equation $m = (1.000\,\text{kg litre}^{-1}) \times V$. This means that the numerical value of the mass in kilograms is the same as the numerical value of the volume in litres.

The first of the methods described above is likely to be the most convenient if you have suitable scales.

Determining the temperature change. You may have had some difficulty deciding how to determine the temperature change without a thermometer. The final temperature is fairly straightforward; if you heat the water to its boiling temperature, then it will be at about 100 °C (unless you live at a very high altitude), so this is a reasonable value to use for the final temperature.

There are various ways that you can start off with water at a known temperature:

- If you leave a jug, or bottle, of water in your kitchen for a few hours, or better still overnight, it will be at room temperature — whatever that is in your kitchen. Most houses will be at a temperature within a few degrees of 20 °C, and this would be a reasonable estimate to make for the initial temperature.
- Alternatively, you could leave a jug of water in the refrigerator overnight, in which case its temperature would be within a couple of degrees of 4 °C, the optimum temperature for a domestic refrigerator.
- As a third option, if you leave ice in water for long enough then the ice–water mixture will reach a steady temperature of 0 °C and will remain at this temperature until all of the ice has melted. (You must be sure that you don't have any ice in the kettle at the start of the experiment though.)

Decide which method you will use to get water at a known initial temperature, and plan your preparations so that the water is at this temperature when you are ready to start the experiment.

Now return to the notes for this activity.

Tasks 2 and 3

Table 6.1.2 shows a typical set of measurements, and the way that the specific heat was calculated from them.

Now return to Task 4 in the notes for this activity.

Task 4

Here is what a member of the Course Team noted down after he had completed the experiment (see also Table 6.1.2). Your notes may be different because you may have tackled the experiment in a different way.

(a) Scales had 25 gram divisions, so mass measurements have uncertainty of ±25 g.

Water left in kettle overnight before experiment started. House at about 20 °C, so assume starting temperature 20 °C ± 2 °C.

Final temperature 100 °C (normal boiling temperature of water). Therefore temperature difference 80 °C ± 2 °C.

Time interval difficult to measure — not sure when the water was 'really' boiling; stopped heating when the boiling got fierce, but not sure whether the water reached 100 °C before then. Uncertainty in time about ±10 s.

(b) Some electrical energy goes into internal energy of kettle — it gets hot — and some heats up surrounding air. So not all of energy supplied heats water — heat transferred to water is less than electrical energy supplied, so the true value of specific heat will be less than that calculated.

(c) Largest uncertainty — energy used to heat kettle itself. Therefore need to find way to measure how much energy is used for this in order to get a better value for the specific heat. Could reduce energy lost to the air by putting a towel round the kettle. Could use a thermometer to measure starting temperature.

Note that the specific heat of water has been measured by many experimenters, and the accepted value (the value published in tables of scientific data) is $4.179\,6 \times 10^3\,\text{J kg}^{-1}\,\text{°C}^{-1}$ at 25 °C and $4.216\,0 \times 10^3\,\text{J kg}^{-1}\,\text{°C}^{-1}$ at 100 °C. To two significant figures this is $4.2 \times 10^3\,\text{J kg}^{-1}\,\text{°C}^{-1}$ over the temperature range of this experiment.

Now return to Task 5 in the notes for this activity.

Task 5

A suitable conclusion would be as follows:

> The value obtained for the specific heat of water in this experiment was $4.8 \times 10^3\ \text{J kg}^{-1}\,\text{°C}^{-1}$. This is about 15% higher than the accepted value, which is $4.2 \times 10^3\,\text{J kg}^{-1}\,\text{°C}^{-1}$. The main reasons for this difference are that no allowance was made for the energy that was used to heat the kettle itself or the energy lost to the surrounding air.

You should enter the accepted value in the blank space in Table 6.1 in Book 5. You may also like to note your result below the table.

Table 6.1.2 Completed version of Table 6.1.1. Results from an experiment to measure the specific heat of water.

	Results	Comments/notes
mass of empty kettle	775 g	scales read to 25 g divisions
mass of kettle + water	2 200 g	
mass m of water in kettle	1 425 g = 1.425 kg	
power rating P of kettle	2.0 kW = 2 000 W	label on bottom
starting time (power on)	6:36:00	used digital watch with seconds display
finishing time (power off)	6:40:34	
time interval t for heating	4 min 34 s = 274 s	
starting temperature	20 °C	water stood overnight at room temp.
finishing temperature	100 °C	
temperature change ΔT	80 °C	
electrical energy supplied $E = P \times t$	5.5×10^5 J	$E = 2.0 \times 10^3$ W $\times$ 274 s = 5.5×10^5 J
specific heat of water $c = \frac{q}{m\Delta T}$	4.8×10^3 J kg^{-1} °C^{-1}	$c = \frac{5.5 \times 10^5 \text{ J}}{1.425 \text{ kg} \times 80\,^\circ\text{C}} = 4.8 \times 10^3$ J kg^{-1} °C^{-1}

Activity 6.2

Task 1

The values that you should have entered in Table 6.2.1 are 225 g for the mass of water converted into vapour, which is equal to 0.225 kg, and 4 minutes for the time interval for heating, which is 240 s. Here is how the Course Team experimenter then laid out his calculations and his conclusion.

Energy E supplied to the kettle is power P multiplied by time t, so

$$E = Pt = 2.0\,\text{kW} \times 240\,\text{s} = 2.0 \times 10^3\,\text{W} \times 240\,\text{s}$$

$$= 4.8 \times 10^5\,\text{J}$$

We assume that all of this energy is transferred as heat q to the water in the kettle. Latent heat of vaporization L is the heat transferred to the water divided by the mass m of water converted into vapour, so

$$L = \frac{q}{m} = \frac{4.8 \times 10^5\,\text{J}}{0.225\,\text{kg}} = 2.13 \times 10^6\,\text{J kg}^{-1}$$

Since the power rating of the kettle was specified to only two significant figures, the result is $L = 2.1 \times 10^6\,\text{J kg}^{-1}$.

Task 2

The notes the Course Team member made about the uncertainties are given in Table 6.2.2.

The uncertainty of ±30 g for the mass evaporated assumes that the value recorded for the initial mass could have been 15 g too high and the value recorded for the final mass could have been 15 g too low, or vice versa. This gives an upper limit to the uncertainty.

Note that the last uncertainty listed could be reduced by wrapping the kettle in a towel to reduce energy losses. Note also that we don't have to worry about energy required to heat the kettle: the vaporization of the water takes place at the boiling temperature, so the temperature of the kettle is not changing.

Task 3

The Course Team member's conclusion is given in Table 6.2.2.

Note that the accepted value for the latent heat of vaporization is $2.3 \times 10^6\,\text{J kg}^{-1}$ (to two sig. figs). You should insert this value in the space that has been left blank in Table 6.2 in Book 5.

Table 6.2.2 Further details for the experimental account on page 13. The 'Discussion' and 'Conclusion' would follow the 'Results' section.

Account	Comment
Discussion	
Sources of uncertainty: measured values of the time and the mass, and value quoted for the power of the kettle.	Accounts of experiments often include a separate 'discussion' section, though this can sometimes be part of the results section. The notes here (and your response to Task 2) would form the basis of a discussion section.
Time interval for heating: uncertainty is small, since it is possible to measure the times at which the power is switched on and switched off to the nearest second or less; maximum uncertainty in time interval is ±2 s.	
Mass converted into vapour: with the scales used in this experiment the uncertainty in a mass measurement is likely to be about half of a scale division, which is about 15 g; since the mass converted into vapour is the difference between two measurements of mass, maximum uncertainty in mass evaporated is ±30 g.	
Kettle power rating: the rating is specified as 2.0 kW, and so we assume that this means that the rating lies between 1.95 kW and 2.05 kW, since values within this range would be rounded to 2.0 kW to two significant figures. So the uncertainty here is ±0.05 kW.	
The uncertainties that are difficult to estimate are those associated with energy losses from the kettle. The water in the kettle must have cooled a little while it was being weighed, so some of the energy supplied in the 4 minute period was used to bring the water back to the boiling temperature. Also, some of the electrical energy was used to heat up the surrounding air rather than to vaporize water. This means that there is an uncertainty in the amount of heat transferred to vaporize the water.	
Conclusion	
The value for the latent heat of vaporization of water was measured as $2.1 \times 10^6\,\text{J kg}^{-1}$.	The conclusion is the final part of the account, and it encapsulates in a few sentences the main outcomes of the experiment.

Activity 9.1

Studying this block should have developed your skills in all of the areas listed in the 'questionnaire' and hopefully you recorded an improvement in your assessment of your ability (unless you were already at the top end of the scale when you started the block!). If there are areas with which you are not yet fairly confident, then the list below indicates parts of Book 5, the maths software or *SGSG* that you might find helpful. If you require further help you should discuss options with your tutor.

Using symbols for physical quantities: Activity 3.1; Block 3 Box 4.1

Using proportionalities: Box 3.1; Block 3 Box 12.1

Deciding which equations are required: refer to your glossary for Activity 3.2, and scan through the boxed equations and the summaries to remind yourself of the meaning of the important equations

Rearranging and solving algebraic equations: Box 3.2; 'Algebraic manipulation' software on Block 3 DVD-ROM; *SGSG* MH9

Combining equations to solve problems: Box 3.3

Substituting values in equations and calculating the correct answer: work through some of the numbered questions again.

Getting the units right: Box 3.4; *SGSG* 5: 4

Getting the significant figures right: Block 2 Box 2.1; *SGSG* MH6

Setting out the answers to maths questions: *SGSG* 4:5

Having a strategy for solving problems: Activities 3.3, 3.4 and 4.1

This last skill, problem solving, is an important one, and we will return to it in many of the later blocks. You will find that the approach that you used here — of breaking down the solution to a problem into a sequence of different stages — is one that is applicable in many different contexts.

Objectives for Block 5

The objectives state what you should understand and what you should be able to do after studying the block.

The numbers of questions and activities that test each objective are given in italics. In the margin next to some objectives are references to *The Sciences Good Study Guide (SGSG)*, giving the chapter: section number or Maths Help (MH) number, or to DVD material, where you can find additional support.

Science content

1 Explain the meaning of, and use correctly, all the terms printed in **bold** in the text.

2 Describe in words the various energy transfers and conversions in a given sequence of events, and explain what is meant by work, kinetic energy, gravitational energy, strain energy, internal energy, heat, chemical energy, electrical energy and power. (*Questions 3.11, 4.3 and 6.3*)

3 State the law of conservation of energy and apply it to a variety of energy conversions. (*Questions 4.4–4.6, 5.1, 8.3 and 8.4*; *Activities 4.1 and 5.1*)

4 Recall the meaning of the following equations, and use them correctly:

$W = Fd$	(*Questions 3.1, 3.2, 3.6, 3.10 and 4.3*)
$E_k = \frac{1}{2}mv^2$	(*Questions 3.10, 3.13, 4.3–4.6*; *Activities 3.3, 3.4, 4.1 and 5.1*)
$\Delta E_g = mg\Delta h$	(*Questions 4.4–4.6 and 5.1*; *Activities 4.1 and 5.1*)
$P = \frac{E}{t}$	(*Questions 3.12, 3.13 and 8.3*; *Activities 6.1 and 6.2*)
$q = mc\Delta T$	(*Question 6.1*; *Activity 6.1*)
$q = Lm$	(*Questions 6.4 and 6.5*; *Activity 6.2*)
$I = \frac{Q}{t}$	(*Question 7.5*)
$\Delta E_e = Q\Delta V$	(*Question 7.3*)
$P = I\Delta V$	(*Questions 7.4 and 7.5*)
$E = mc^2$	(*Question 8.4*)

5 Recall that all freely falling objects have an acceleration $g = 9.8\ \text{m s}^{-2}$ close to the Earth's surface, and that the gravitational force on an object of mass m is mg. (*Questions 4.1 and 4.2*)

6 Describe how the internal energy of an object is related to the kinetic and potential energies of its constituent molecules, and how the internal energy can be changed by doing work on an object or by transferring heat to it. (*Questions 3.11 and 6.3*)

7 Describe the relationship between the absolute scale of temperature and the Celsius scale, and convert temperatures from K to °C, and vice versa. (*Questions 6.2, 6.4 and 8.3*)

8 Recall the main properties of electric charge, the distinction between conductors and insulators, and that electric current is the rate of flow of charge. (*Questions 7.1, 7.2 and 7.5*)

9 Describe how the Earth's GMST would change if there were no evaporation of water from the surface, and if there were no atmosphere. (*Question 8.3*)

10 Recall that mass is a form of energy. (*Question 8.4*)

Science skills

SGSG 8 :3–5

11 Plan and carry out an experiment, make measurements, tabulate and analyse data, assess uncertainties in measurements, and discuss improvements that could be made to the experiment. (*Activities 5.1, 6.1 and 6.2*)

Communicating science skills

12	Recall that written accounts of scientific experiments are generally presented in a standard format. (*Activity 6.2*)	*SGSG* 9: 5.4
13	Use symbols and equations to communicate scientific ideas. (*Most questions and activities involving calculations*)	*SGSG* MH9
14	Present written answers to numerical questions in an appropriate way. (*Most questions and activities involving calculations*)	*SGSG* 4: 5

Mathematical skills

15	State the SI units of force, energy, power, charge, current and voltage difference, and use these units correctly in calculations. (*Most questions and activities involving calculations*)	*SGSG* 5: 4.1
16	Convert a proportionality into an equation by introducing a constant of proportionality. (*Box 3.1*)	
17	Select appropriate algebraic equations to solve various problems, rearrange equations, and solve them by substituting appropriate values for the algebraic symbols. (*Questions 3.3–3.6, 3.10, 3.12, 3.13, 4.3–4.6, 5.1, 6.1, 6.4, 6.5, 7.3–7.5, 8.3 and 8.4*; *Activities 3.1, 3.3, 3.4 and 4.1*)	Block 3 DVD 'Algebraic manipulation'; *SGSG* MH9
18	Solve an algebraic equation by substituting an algebraic expression from another equation. (*Questions 3.7, 3.8, 4.4–4.6*; *Activity 4.1*)	
19	Evaluate squares and square roots of numbers and algebraic expressions. (*Questions 3.9 and 4.3–4.6*)	*SGSG* MH7
20	Express answers to calculations to the appropriate number of significant figures and with the correct units. (*All questions and activities involving calculations*)	*SGSG* MH6

Effective learning skills

21	Develop, apply and refine a strategy for solving problems. (*Activities 3.3, 3.4 and 4.1*)	
22	Produce a glossary of symbols, equations and units to aid understanding and recall of each of them. (*Activity 3.2*)	
23	Assess abilities in certain areas, and take action to improve skills in those areas. (*Activities 3.1 and 9.1*)	

Appendix 1 What to do if you are short of time

This brief guide to the activities in Block 5 should help you to decide for yourself whether you need to do a particular activity. Remember, though, that if you have the time you should aim to do *all* the activities in order to obtain the full benefit from your study.

The five numbered columns in the table below offer advice about each activity as follows:

1 essential that you do this activity at the particular point in Book 5 where it appears;

2 important, but there is more flexibility about when you do this activity, although you should try to complete it before moving onto the next section of Book 5;

3 may not be essential if you have some background already in the topic or skill, or have found earlier, similar activities straightforward;

4 could be left until later on, or dropped altogether if you are really short of time;

5 forms a useful tool for the revision of your maths skills at various stages later in the Course, or in higher level Science courses, where these skills are needed.

The last column on the right contains additional advice about some of the activities.

Block 5 activities

Activity	Category					Comments
	1	2	3	4	5	
3.1			✓			
3.2		✓				Particularly important if you find algebra difficult.
3.3	✓					
3.4	✓					
4.1	✓		✓			
5.1			✓			
6.1		✓				
6.2		✓				
9.1					✓	

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